Preliminary Assessment of the GSFC Clear Flag using Granules #5, 21, 89, 90, 115, 116, 212, & 236 of AIRS measurements taken on June 14, 2002

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I have successfully run all 8 granules in my off-line system (steps: NOAA-LAC, MIT, INITIAL and FINAL products) and compared all steps and results with the ECMWF forecast. These experiments did NOT utilize any TUNING; however, the following modifications were made

- **rejection criteria were relaxed, since there are systematic biases, channeling, etc.**
- **The R-branch of the 4.3 μm band were removed due to spectroscopy errors in the current RTA.**
- **I added a noise co-variance radiance error estimate for the fact that the frequencies were not exact.**
- **I ran with the +16 μm, nominal, and, -16 μm RTA. The results were best with -16 μm RTA, slightly worse with the nominal RTA and degraded significantly with the +16 μm RTA.**

While we all agree that running cloudy retrievals is premature at this time, the fact that the off-line system is working allows the following

- **transformation from radiance space to geophysical space provides insight and 1st order sanity checks**
- **development and validation of L2 flow and robustness issues**
- **ability to use a plethora of diagnostics, such as radiance residuals w.r.t. ECMWF and retrieval solution(s).**

Joel's Clear Flag

Joel's cloud clearing algorithm is currently being run as installed pre-launch in the PGE. This algorithm determines if the golf-ball FOR is clear and requires

- **The microwave retrieval products with estimates of retrieval errors.**
- **The initial cloud clearing algorithm, which requires the RTA.**

The methodology uses two criteria to decide if the scene is clear.

1. **The first compares the cloud cleared radiances to the average of the 9 IR radiances. This is a measure of the amount of cloud clearing**

$$\Theta_{corr} = \frac{1}{N} \sum_{\nu=800 \ cm^{-1}}^{900 \ cm^{-1}} \frac{R_{ccr} - < R >}{\left.\frac{\partial B_\nu(T)}{\partial T}\right|_{T=\Theta_{ccr}}} \quad \leq \quad 0.1 \ K \tag{1.1}$$

   and a poor MIT retrieval or IR cloud clearing step will tend to fail this test.

2. **The second criterion uses the cloud clearing eigenvalues which are a measure of scene variability. For ocean the pre-launch simulation determined a reasonable threshold of $\lambda \leq$ 125.**

$$\lambda_k = U^T_{k,j} \cdot S^T_{j,n} \cdot N^{-1}_{n,n'} \cdot S_{n',j} \cdot U_{j,k} \tag{1.2}$$

   - $U_{j,k}$ **is the eigenvector and** λ_k **is the eigenvalue of the matrix** $S^T_{j,n} \cdot N^{-1}_{n,n'} \cdot S_{n',j}$
   - **the** S **matrix is the difference of each IR scene from the average of all 9 IR FOV's,** $S_{j,n} = R(n,j) - \frac{1}{9}\sum_{i=1}^{9} R(n,i)$
   - **and** N **is the observed minus calculated (obs-cal) noise covariance matrix**

The obs-cal noise covariance matrix

The observed minus calculated noise covariance matrix includes the following terms

- **the NEΔN values taken from v6.1 channel properties file (June 29, 2002).**
- **error estimates in the computed radiances for surface parameters (T_{skin}, ϵ_ν, ρ_ν), temperature profile, and moisture profile. The radiance error due to a geophysical parameter Y is estimated as**

$$E_{n,Y} = \frac{\partial R_n(X,Y)}{\partial Y}\Big|_{X,Y} \cdot \delta Y \tag{1.3}$$

- **an estimate of the radiance error due to the difference between observed and computed frequencies**

The Radiance Error due to RTA/obs frequency differences

The "noise" due to a difference between the employed RTA and the observed radiances can be estimated by

$$\mathrm{NE\Delta N}_{\delta f}(n) = \frac{\partial R_n}{\partial f} \cdot \delta f_n \tag{1.4}$$

Per Steve Gaiser (via Scott Hannon) the instrument on June 14th was -13 μm. I used the two RTA's which bracket the observed frequencies to estimate the radiance error over the 16 μm shift.

$$\frac{\partial R_n}{\partial f} = \frac{R_n(nominal) - R_n(-16\mu m)}{f_n(nominal) - f_n(-16\mu m)} \tag{1.5}$$

and estimated the observed (L1b) frequencies using the -16 μm RTA for an instrument at -13 μm by

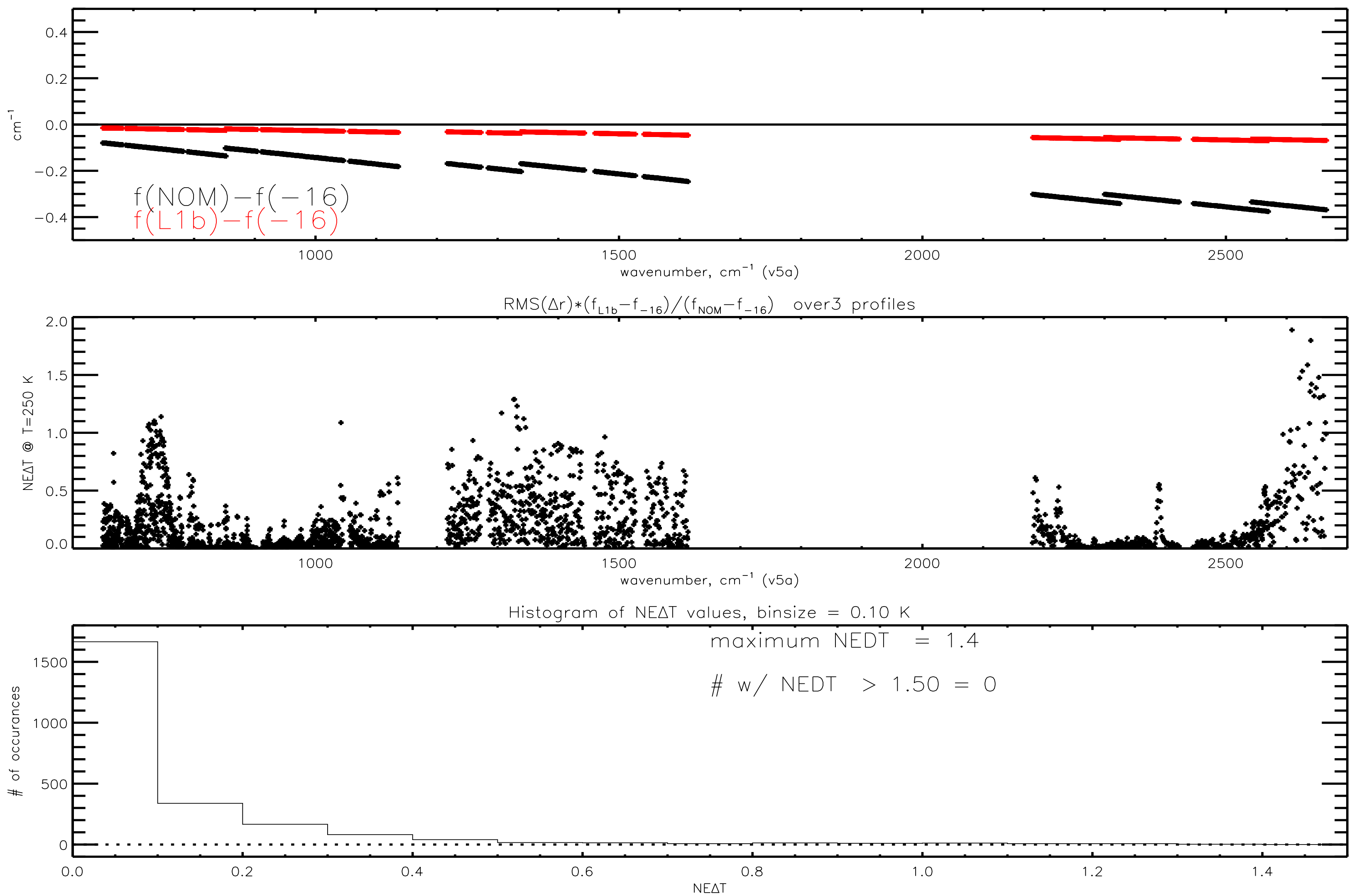
$$f_n(l1b) = f_n(-16\mu m) + \frac{3}{16}\left(f_n(nominal) - f_n(-16\mu m)\right) \tag{1.6}$$

and used the following as the estimate of the frequency difference in Eqn. 1.4

$$\delta f_n = f_n(l1b) - f_n(-16\mu m) \tag{1.7}$$

When using other RTA's this process was repeated with the appropriate RTA's.

The Radiance Error USED in this analysis



Methodology

- **Run the complete retrieval system**
- **Select those retrievals that**

  1. **sufficiently converge in all steps**
  2. **% land = 0 (Masuda & English emissivity models are used)**
  3. **pass Joel's CLEAR test using cloud cleared radiances**
  4. **run daytime (G115,116,212) and nighttime (5,21,89,90,236) granules separately**
  5. **Then, re-run retrieval with $< R >$ instead of cloud cleared radiance and kick all golf-balls in which the retrieval degrades significantly**

59 Daytime "CLEAR" Golf-balls

Granule # 115

978 1032 1035 1038 1063 1064 1093 1122 1123 1135 1213 1216 1217 1218 1220 1276
1339

Granule # 116

1368 1369 1399 1400 1429 2414 2416 2446 2447 2477

Granule # 212

2895 2953 2983 3045 3048 3103 3135 3141 3171 3280 3432 3434 3464 3487 3517 3709
3732 3766 3796 3827 3828 3855 3858 3968 3982 4006 4008 4009 4037 4038 4041 4043

112 Nighttime "CLEAR" Golf-balls

Granule # 5

431	432	490	491	522	619	620	639	647	650	651	654	669	670	671	679
681	698	706	709	713	714	732	737	741	762	764	765	767	769	788	794
796	802	803	820	821	822	828	849	850	852	855	862	881	885	887	888
1010															

Granule # 21

2210 2211 2315 2588

Granule # 89

3036	3160	3186	3192	3199	3224	3225	3251	3255	3310	3320	3326	3341	3367	3372	3373
3382	3401	3403	3404	3416	3458	3504	3534	3551	3615	3622	3646	3650	3653	3655	3683
3888															

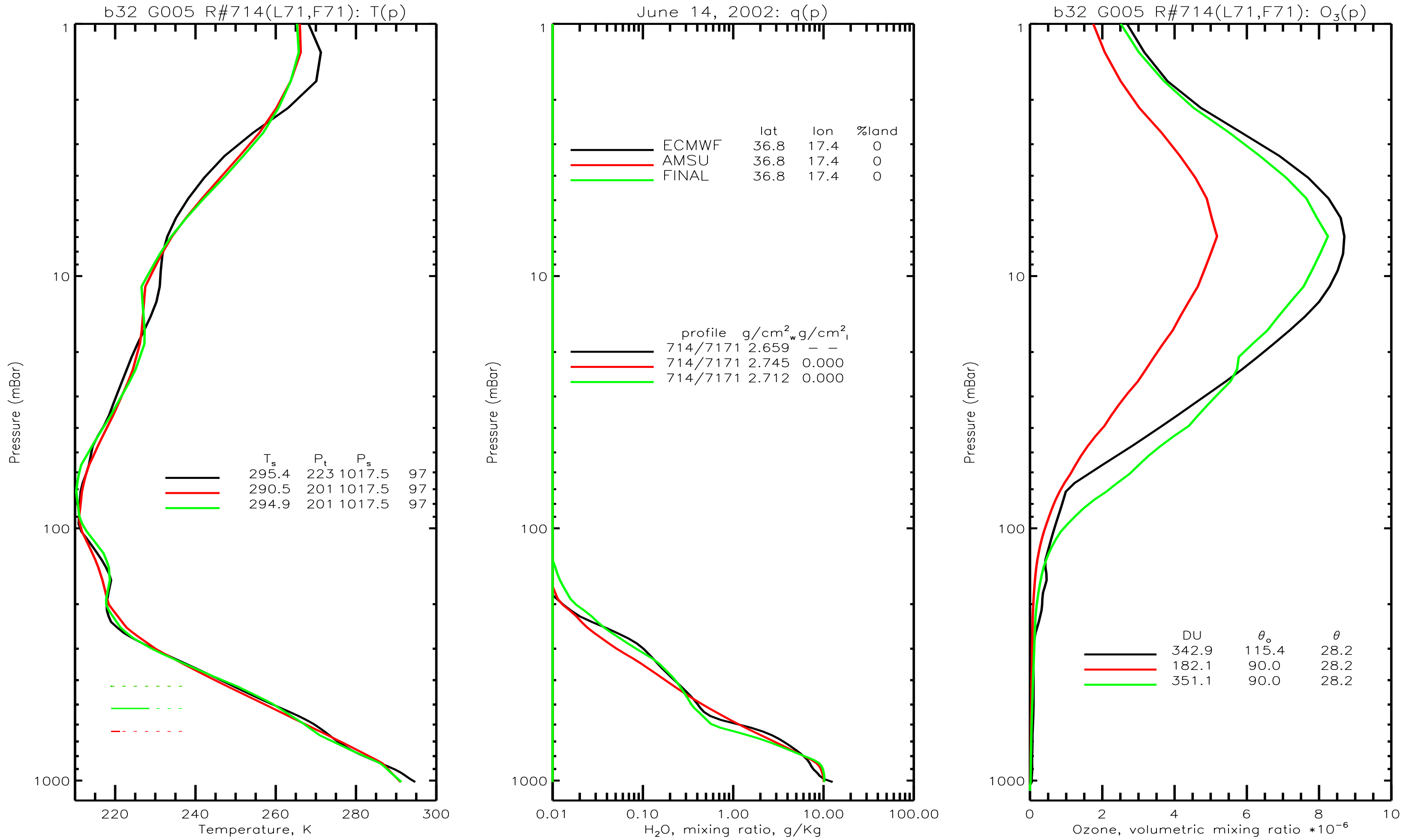
Granule # 90

4364	4389	4395	4605	4606	4752	4758	4822	4912	4916	4993	4994	4997	5024	5026	5113
5234	5267	5295	5298	5327											

Granule # 236

5718 5750 5810 6042 6073

Example T(p),q(p), and O3(p) profiles
Granule #5, Golf-ball # 714 (centered at Line 71, FOV 71)



The black line is the ECMWF forecast. The retrieval begins with a UARS/NCEP climatology. The red line is the MIT/GSFC AMSU retrieval, and the green line is the FINAL retrieval.

Radiance Residual Figures: Labels

There are three panels. In all cases these are the subset of clear retrievals with the number of profiles shown in the figure (112 night, 59 day).

Panel 1 Agreement of the observation with ECMWF

BLUE the difference between radiances computed from the ECMWF forecast ("TRU") and observed IR radiances in the golf-ball ("$< R >$" = the average of the 9 IR footprints)

GREEN the RSS of NEΔN/3 + $\mathrm{NE\Delta N}_{\Delta f}$

Panel 2 Ability of Retrieval to Converge. The difference between observed average radiances (NOTE: in these runs $\eta_x \equiv < R >$) and radiances computed from the retrieval state.

BLUE after the AMSU/HSB retrievals ("$\mathrm{R}_{\mathrm{ret(1)}}$").

RED after the FINAL retrieval ("$\mathrm{R}_{\mathrm{ret(2)}}$")

GREEN the RSS of NEΔN/3 + $\mathrm{NE\Delta N}_{\Delta f}$

Panel 3 Agreement of the retrieval with ECMWF. The difference between radiances computed from the ECMWF forecast ("$\mathrm{R}_{\mathrm{TRU}}$") and radiances computed from the retrieval state:

BLUE after the AMSU/HSB retrievals ("$\mathrm{R}_{\mathrm{ret(1)}}$").

RED after the FINAL retrieval ("$\mathrm{R}_{\mathrm{ret(2)}}$")

GREEN the RSS of NEΔN/3 + $\mathrm{NE\Delta N}_{\Delta f}$

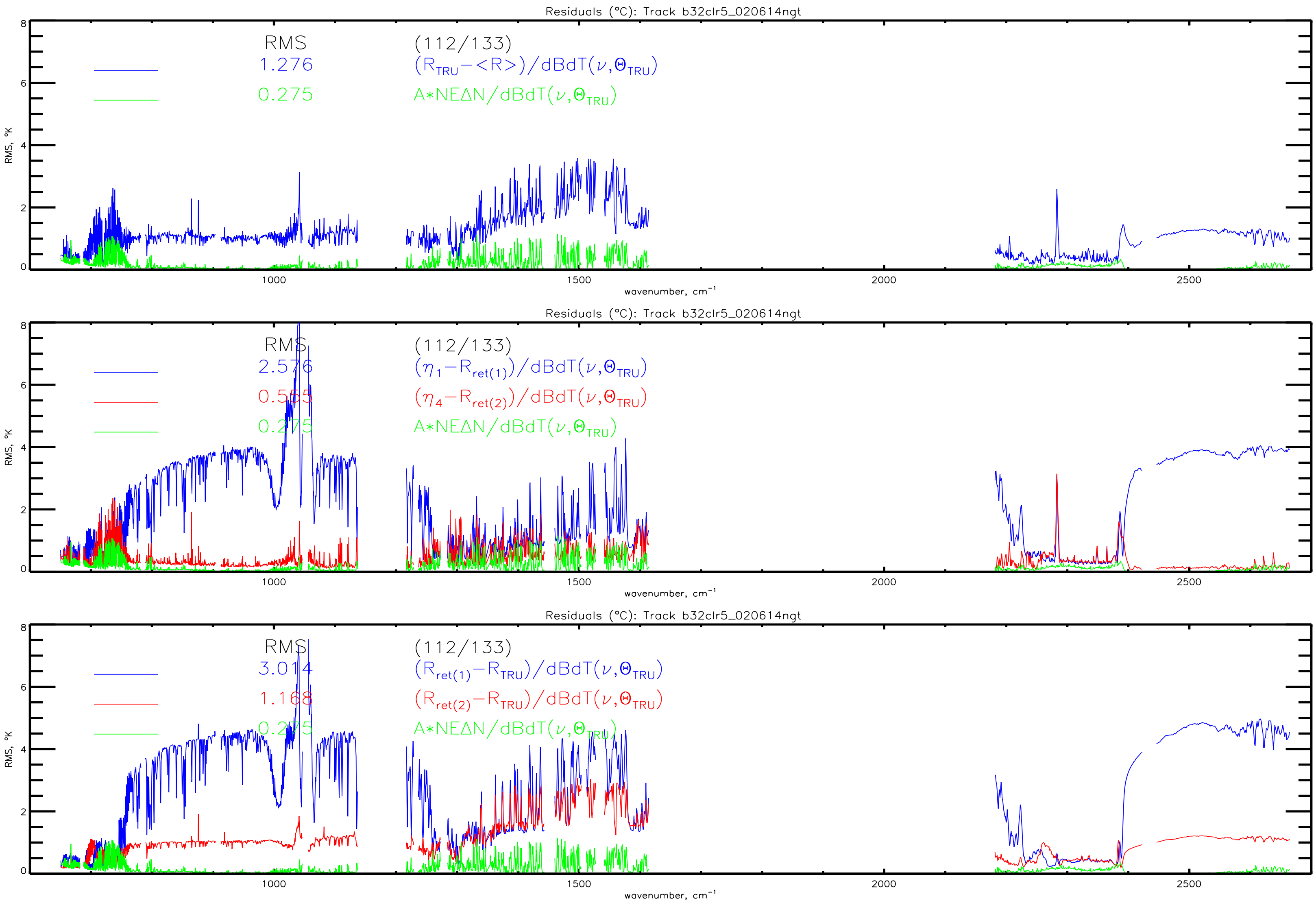
Radiance Residual Figures: Discussion

On the following pages I show RMS and BIAS's of brightness temperature difference, $\Delta\Theta(n)$ for the "CLEAR" cases. In these figures the difference between two radiances, $R_1(n)$ & $R_2(n)$, are computed as follows

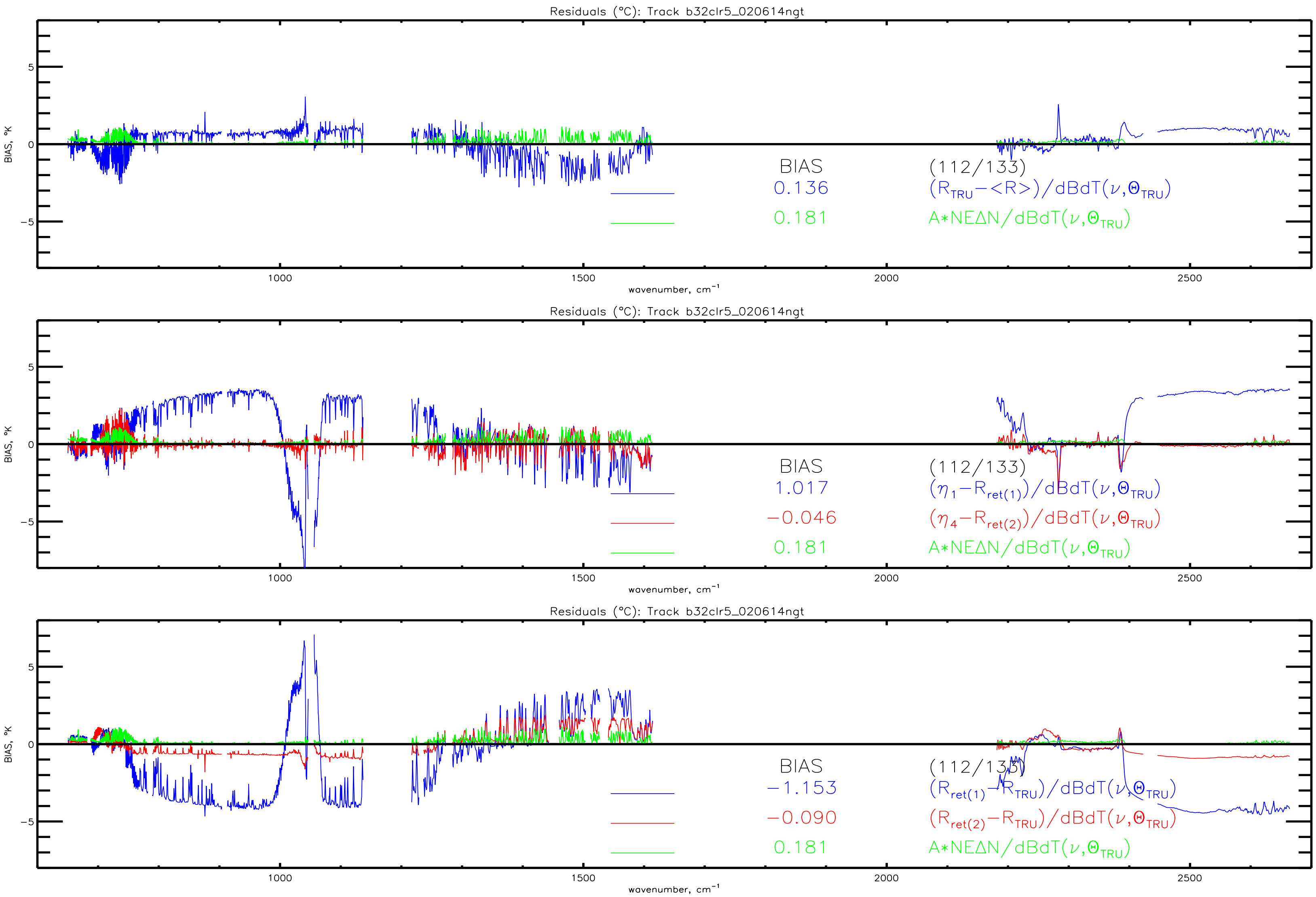
$$\Delta\Theta(n) = \frac{R_1(n) - R_2(n)}{\left.\frac{\partial B_\nu(T)}{\partial T}\right|_{T=B_\nu^{-1}(R_{\mathrm{ECMWF(n)}})}} \tag{1.8}$$

- **in the wings of the 15 μm and the 4 μm bands the agreement with ECMWF is excellent.**
- **The window regions agree within 1 K and the observations are biased cold w.r.t. ECMWF which is consistent with some cloud contamination and/or biases in buoy temperatures.**
- **The retrieval makes a dramatic improvement w.r.t. ECMWF between the microwave step (this step used climatology as fg) and the infrared retrieval. Significant improvements can be seen in the surface, O_3 (1000 cm^{-1}) and CO (2200 cm^{-1}).**
- **The ability of the FINAL retrieval to minimize residuals in the all parts of the spectrum is excellent. This is seen by comparing the RED and GREEN curves in Panel #2.**
- **comparison of the FINAL retrieval with ECMWF is the same as obs-ECMWF (another indicator we minimized properly).**
- **Results in daytime are similar EXCEPT we appear to have a non-LTE issue at 4 μm.**

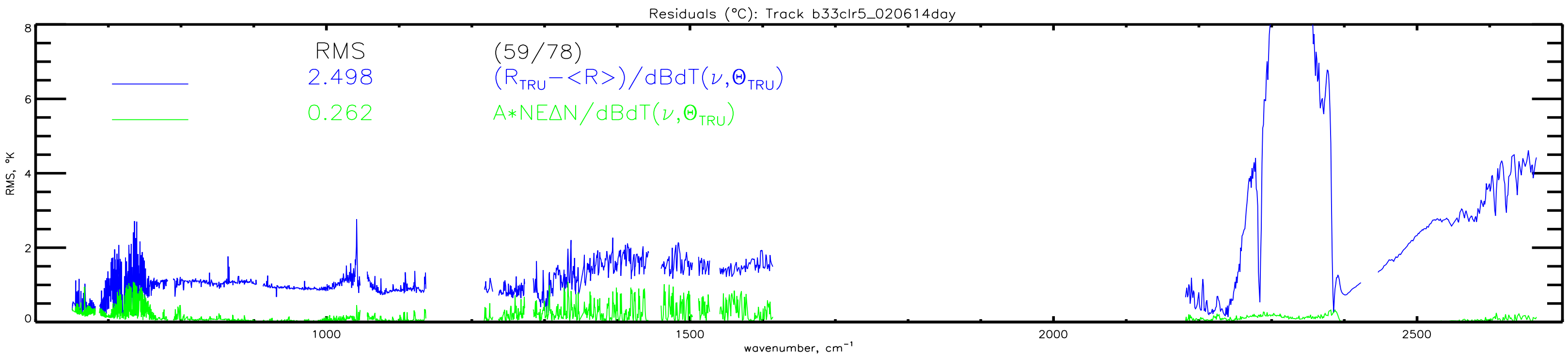
RMS of Nighttime BT differences w.r.t. ECMWF

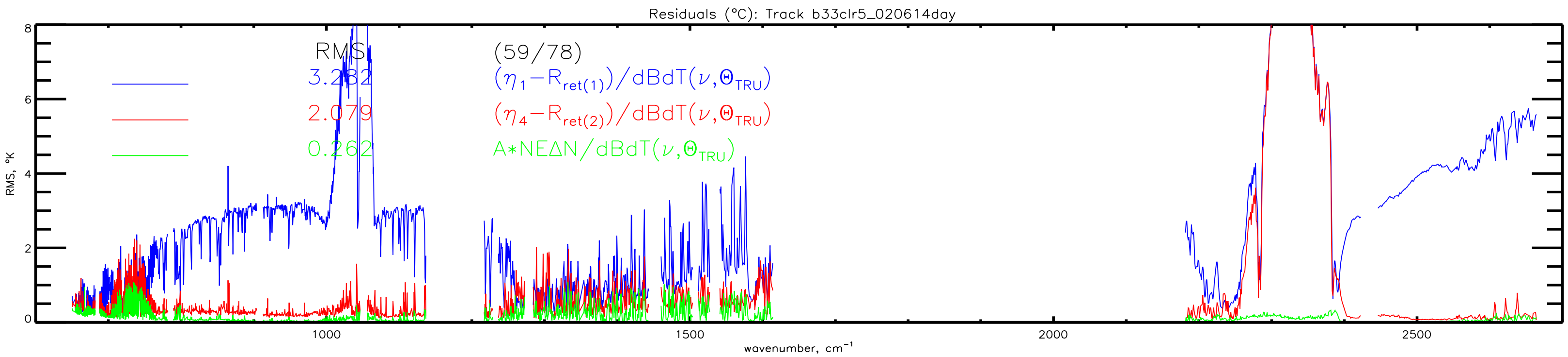


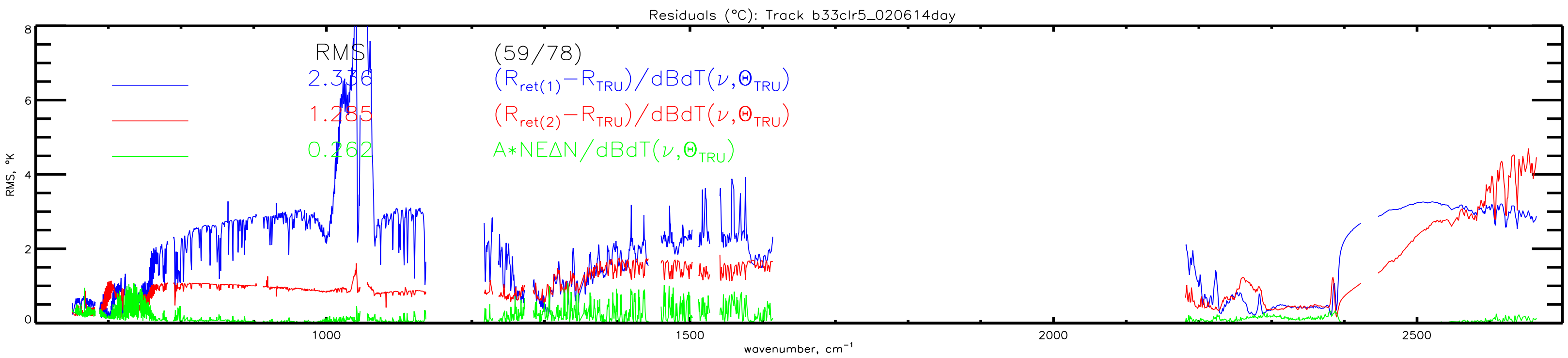
BIAS of Nighttime BT differences w.r.t. ECMWF



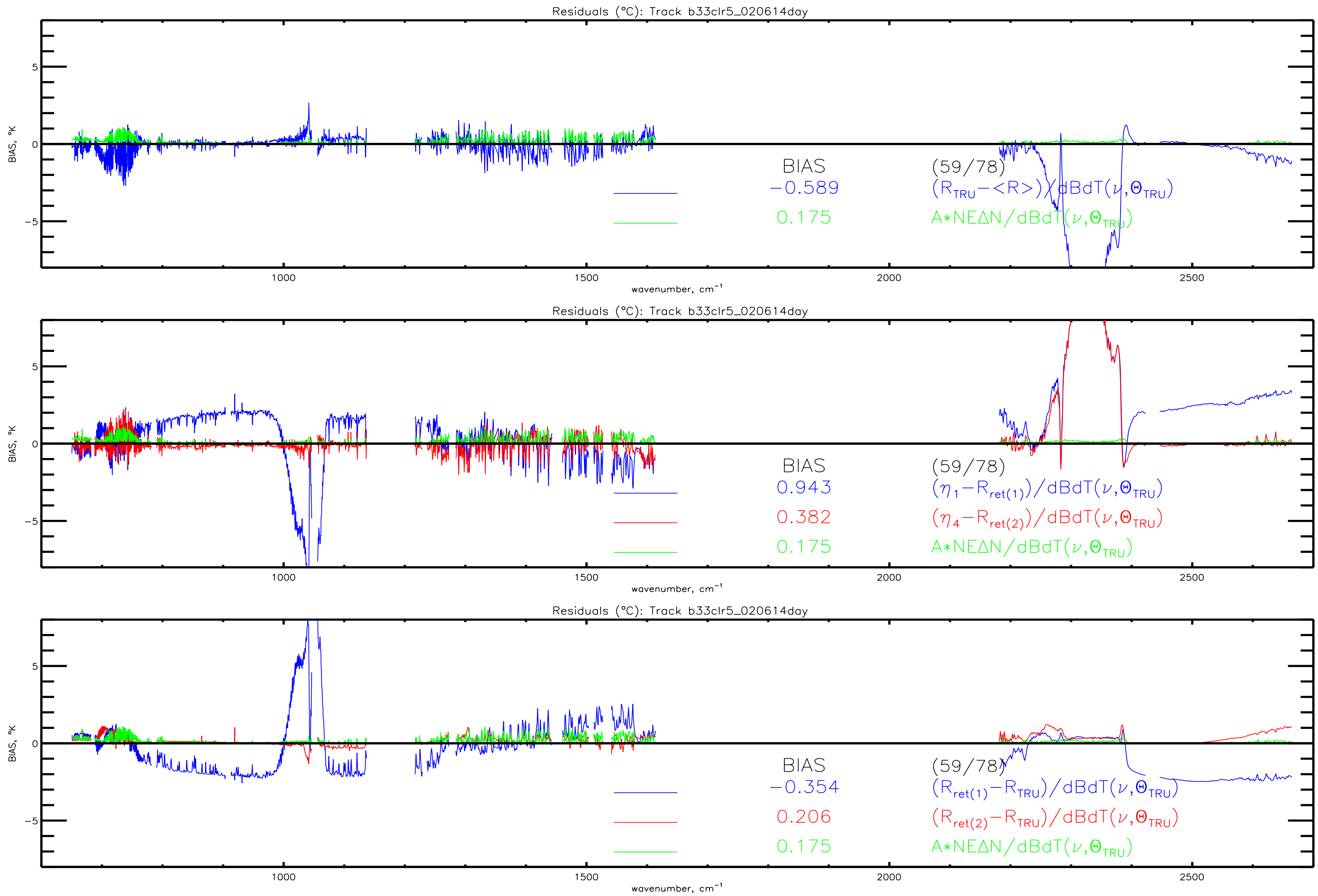
RMS of Daytime BT differences w.r.t. ECMWF







BIAS of Daytime BT differences w.r.t. ECMWF



Needs

- QA and frequency information from the Cal team in L1b HDF files.
- I think these results imply we want a new RTA on the proper frequencies as soon as reasonable for UMBC.

Future Plans

- Keep trying stuff.
- Utilize available data to improve and analyze retrieval performance.
  - Use the obs-cal biases from the CLEAR retrievals (RED line on page 13, middle panel) as a proxy for tuning, re-connect the 4.3 μm channels and apply to CLOUDY retrievals (NOTE: currently accepting 50% of the cases as is).
  - If tuning proxy works, tighten the rejection criteria.
- Isolate robustness issues w.r.t. L1b QA flags in retrieval.
- Quick look (albeit questionable) CO product over Colorado as soon as a reasonably clear dataset is available.